U-Th/He Age Determinations on Volcanic Rocks: A New Tool for Quaternary Geochronology

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RESEARCH OBJECTIVES

Determining the age or time scale of events that have occurred within the past million years is still a challenge to geoscientists and an invaluable tool in evaluating hazards on the time scale of human life. Both radiocarbon and argon-argon (Ar-Ar) dating can be restricted due to a lack of appropriate phases or materials associated with the event. The uranium-thorium/helium (U-Th/He) system, which has been used successfully for thermochronology on zircon and apatite, has potential for dating young volcanic rocks. Our goal is to investigate the viability of applying the U-Th/He dating method to late Quaternary volcanic rocks containing relatively common minerals, such as garnet and olivine, that are not viable for Ar-Ar and radiocarbon dating.

APPROACH

The U-Th/He dating method is based on the radiogenic production of ^{4}He from the alpha decay of U and Th. An age is calculated for the accumulated ^{4}He/U-Th ratio measured in the sample. The accuracy of the age can be compromised by the high mobility of helium in most minerals, gain or loss of ^{4}He by alpha recoil, and isotopic disequilibrium in the U-Th-Pb decay chains. Therefore, to evaluate the viability of the method, we conducted a study of garnet phenocrysts from the 79 A.D. eruption of Vesuvius collected at the Villa of Poppea in Pompeii.

ACCOMPLISHMENTS

To thoroughly test the validity of this method for dating young samples, we had to address several issues: diffusive loss, trapped helium, loss or gain of ^{4}He from alpha recoil, and changing production of ^{4}He because of isotopic disequilibrium in the U and Th decay chains. Crushing and step-heating experiments were done to determine the amount of helium trapped and lost by diffusion. The distribution of U and Th was determined by ion microprobe techniques, and then applied to a simple model to determine loss and gain of helium by alpha recoil. Measurement of the isotopic ratios within the U-Th-Pb decay chains allowed us to correct the calculated age for radioactive equilibrium. Given these considerations, the resultant age of 1,866 ± 243 years indicates that the U-Th/He method is applicable to dating Holocene volcanic samples with accuracy and precision of ± 13% on samples with 20 ppm U.

SIGNIFICANCE OF FINDINGS

The calculated age of the Vesuvius lava validates the U-Th/He method for the dating of young volcanic systems. The age of the Vesuvius samples is extremely small compared to the 1.8 million year age range covered by the Quaternary epoch. Older samples should contain much larger amounts of radiogenic helium for the same amount of U and Th or similar amounts of helium for smaller concentrations of U and Th. The method can now be applied to a range of young lavas that contain fewer mineral phases and were previously not datable using existing Ar-Ar and radiocarbon techniques.

RELATED PUBLICATION

Aciego, S.M., B.M. Kennedy, D.J. DePaolo, J.N. Christensen, and I. Hutcheon, U-Th/He age of phenocrystic garnet from the 79 A.D. eruption of Mt. Vesuvius. Earth and Planetary Science Letters, 2003 (in press).

Renne, P.R., et al., Ar-40/Ar-39 dating into the historical realm, Calibration against Pliny the Younger. Science, 277, 1279-1280, 1997.

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Figure 1. Etching of 79 A.D. eruption of Mount Vesuvius as viewed from the sea. Inset is comparison of ages calculated using Ar-Ar dating (Renne et al., 1997) and U-Th/He dating with age determined by observations of Pliny the Younger.